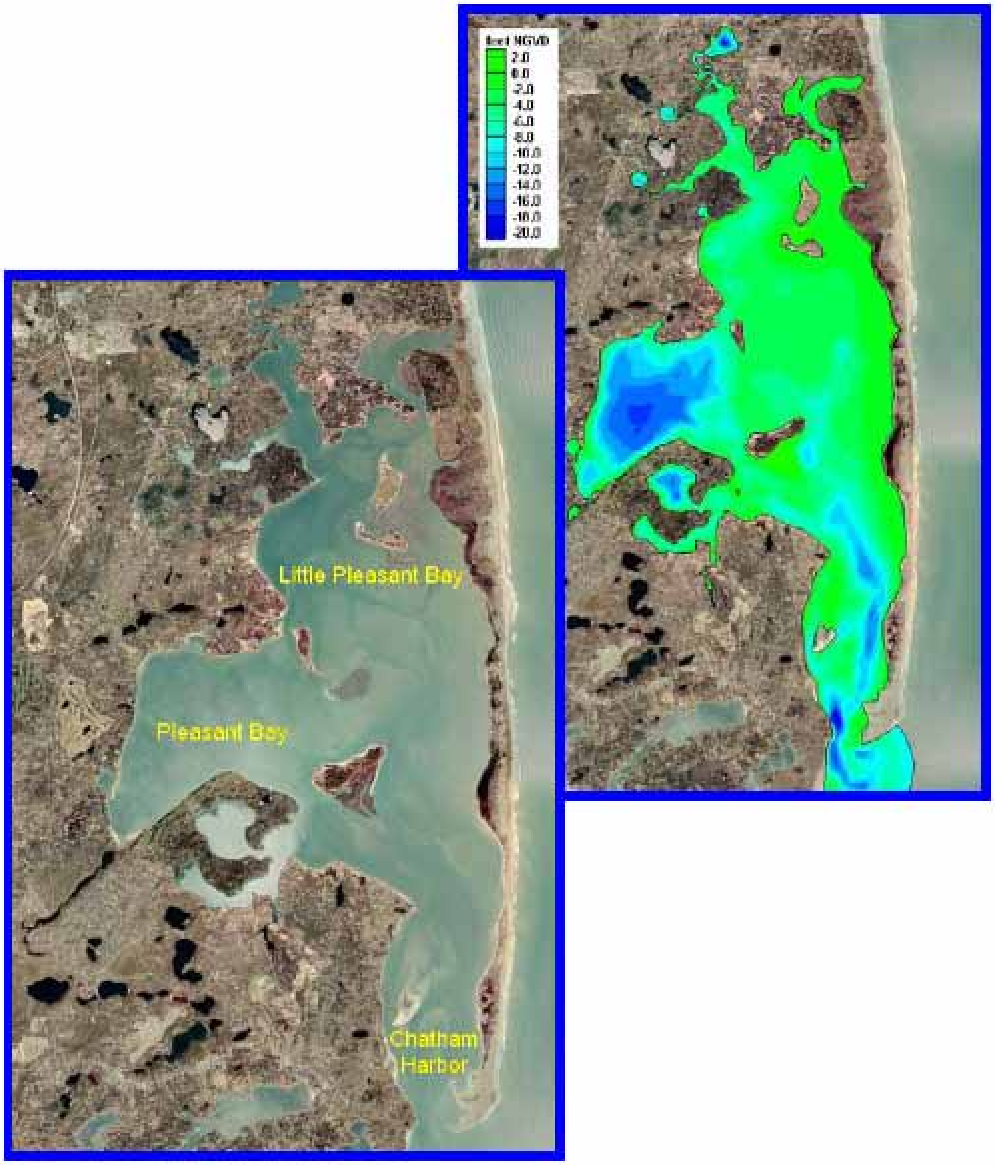
DRAFT
Pleasant Bay System
Total Maximum Daily Loads
For Total Nitrogen

(Report # 96-TMDL-12Control #244.0)



COMMONWEALTH OF MASSACHUSETTS
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July 28, 2006 DRAFT

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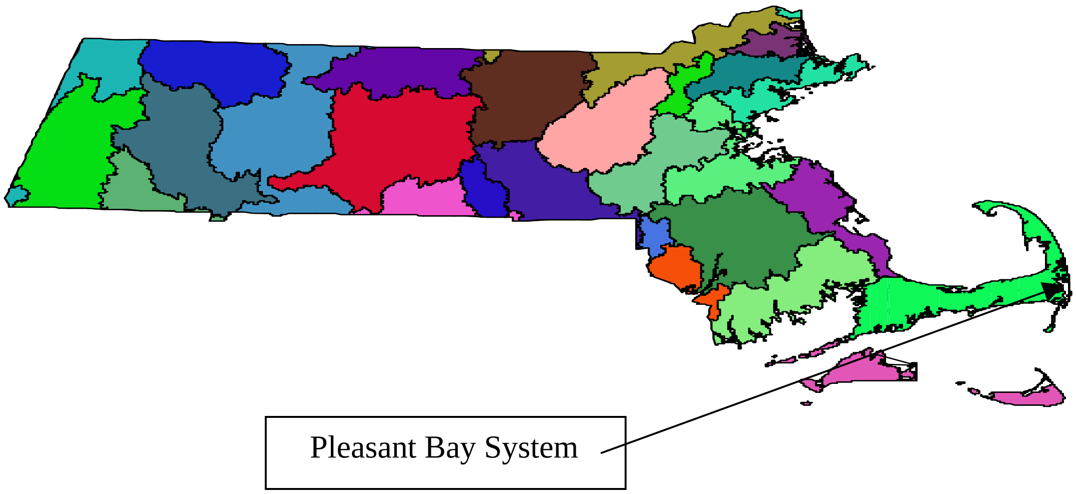


Key Feature: Total Nitrogen TMDL for Pleasant Bay
Location: EPA Region 1
Land Type: New England Coastal
303d Listing:
The waterbody segments impaired and on the Category 5 list include Pleasant Bay.

Data Sources: University of Massachusetts – Dartmouth/School for Marine Science and Technology; US Geological Survey; Applied Coastal Research and Engineering, Inc.; Cape Cod Commission, Towns of Brewster, Chatham, Harwich, and Orleans along with the Pleasant Bay Alliance.
Data Mechanism: Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model
Monitoring Plan: Towns of Chatham, Harwich, and Orleans monitoring program (possible assistance from SMAST)
Control Measures: Sewering, Storm Water Management, Attenuation by Impoundments and Wetlands, Fertilizer Use By-laws

EXECUTIVE SUMMARY

Problem Statement

Excessive nitrogen (N) originating primarily from on-site wastewater disposal (both conventional septic systems and innovative/alternative systems) has led to significant decreases in the environmental quality of coastal rivers, ponds, and harbors in many communities in southeastern Massachusetts. In the Towns of Brewster, Chatham, Harwich, and Orleans the problems in coastal waters include:

- Loss of eelgrass beds, which are critical habitats for macroinvertebrates and fish
- Undesirable increases in macro algae, which are much less beneficial than eelgrass
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life
- Reductions in the diversity of benthic animal populations
- Periodic algae blooms

With proper management of nitrogen inputs these trends can be reversed. Without proper management more severe problems might develop, including:

- Periodic fish kills
- Unpleasant odors and scum
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities

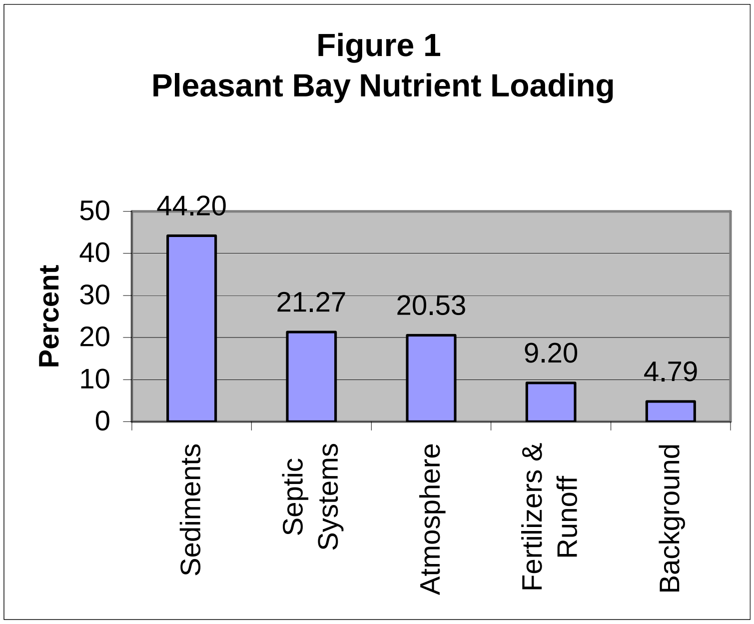
Coastal communities, including Brewster, Chatham, Harwich, and Orleans; rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings may result in complete replacement of eelgrass by macro-algae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a complete loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of Pleasant Bay System coastal waters will be greatly reduced, and could cease altogether.

Sources of nitrogen

Nitrogen enters the waters of coastal embayments from the following sources:

- The watershed
    - On-site subsurface wastewater disposal systems
    - Natural background
    - Runoff
    - Fertilizers
    - Wastewater treatment facilities
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments

Most of the present controllable N load originates from individual subsurface wastewater disposal (septic) systems, primarily serving individual residences, as seen in the following figure.



Target Threshold Nitrogen Concentrations and Loadings

The N loadings (the quantity of nitrogen) to this embayment system ranges from 2.74 kg/day in Bassing Harbor, to 175.11 kg/day in Pleasant Bay. The resultant concentrations of N in these subembayments range from 1.26mg/L (milligrams per liter of nitrogen) in the upper part of Muddy Creek tributary to 0.35 mg/L in the lower part of Chatham Harbor.

In order to restore and protect this system, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below the threshold concentrations that cause the observed environmental impacts. This concentration will be referred to as the target threshold concentration. It is the goal of the TMDL to reach this target threshold concentration, as it has been determined for each impaired waterbody segment. The Massachusetts Estuaries Project (MEP) has determined that, for this embayment system, the bioactive N concentrations of 0.16 – 0.20mg/L are protective. The mechanism for achieving these target N concentrations is to reduce the N loadings to the embayments. The Massachusetts Estuaries Project (MEP) has determined that the Total Maximum Daily Loads (TMDL) of N that will meet the target thresholds range from 2.35 to 155.03 kg/day. This document presents the TMDLs for each impaired water body segment and provides guidance to the affected towns on possible ways to reduce the nitrogen loadings to within the recommended TMDL, and protect the waters for these waterbodies.

Implementation

The primary goal of implementation will be lowering the concentrations of N by greatly reducing the loadings from on-site subsurface wastewater disposal systems through a variety of centralized or decentralized methods such as sewering and treatment with nitrogen removal technology, advanced treatment of septage, upgrade/repairs of failed on-site systems, and/or installation of N-reducing on-site systems.

These strategies, plus ways to reduce N loadings from stormwater runoff and fertilizers, are explained in detail in the "MEP Embayment Restoration Guidance for Implementation Strategies", that is available on the MassDEP website at (http://www.mass.gov/dep/water/resources/restore.htm). The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an adaptive management approach.

Finally, growth within the communities of Brewster, Chatham, Harwich, and Orleans that would exacerbate the problems associated with N loadings, should be guided by considerations of water quality-associated impacts.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state (1) to identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL allocation establishes the maximum loadings (of pollutants of concern), from all contributing sources, that a water body may receive and still meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.

2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point sources (discernable, confined, and concrete sources such as pipes) and non-point sources (diffuse sources that carry pollutants to surface waters through runoff or groundwater).

3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.

4. Specification of load allocations, based on the loading capacity determination, for non-point sources and point sources, which will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDL will serve as a guide for future implementation activities. The MassDEP will work with the Towns to develop specific implementation strategies to reduce N loadings, and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Pleasant Bay System, the pollutant of concern for this TMDL (based on observations of eutrophication), is the nutrient N. Nitrogen is the limiting nutrient in coastal and marine waters, which means that as its concentration is increased, so is the amount of plant matter. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton that impair eelgrass beds and imperil the healthy ecology of the affected water bodies.

The TMDLs for N in the Pleasant Bay System are based primarily on data collected, compiled, and analyzed by University of Massachusetts Dartmouth's School of Marine Science and Technology (SMAST), the Cape Cod Commission, and others, as part of the Massachusetts Estuaries Project (MEP). The data was collected over a study period from 2000 to 2005. This study period will be referred to as the "Present Conditions" in the TMDL since it is the most recent data available. The accompanying MEP Technical Report can be found at http://www.oceanscience.net/estuaries/reports.htm. This report presents the results of the analyses of this coastal embayment system using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model). The analyses were performed to assist the Towns with decisions on current and future wastewater planning, wetland restoration, anadromous fish runs, shellfisheries, open-space, and harbor maintenance programs. A critical element of this approach is the assessments of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure that were conducted on each embayment. These assessments served as the basis for generating N loading thresholds for use as goals for watershed N management. The TMDLs are based on the site specific thresholds generated for each embayment. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision making process in the Towns of Brewster, Chatham, Harwich, and Orleans.

Description of Water Bodies and Priority Ranking

The Pleasant Bay System in Brewster, Chatham, Harwich, and Orleans Massachusetts, at the southeastern edge of Cape Cod, faces the Atlantic Ocean to the south, and consists of a number of subembayments of varying size and hydraulic complexity, characterized by limited rates of flushing, shallow depths and heavily developed watersheds (see Figures 2 and 3 below). This system constitutes an important component of the Town's natural and cultural resources. The nature of enclosed embayments in populous regions brings two opposing elements to bear: 1) as protected marine shoreline they are popular regions for boating, recreation, and land development and 2) as enclosed bodies of water, they may not be readily flushed of the pollutants that they receive due to the proximity and density of development near and along their shores. In particular, the subembayments within the Pleasant Bay System are at risk of further eutrophication from high nutrient loads in the groundwater and runoff from their watersheds. Because of excessive nutrients, waterbody segments within this system are already listed as waters requiring TMDLs (Category 5) in the MA 2002 and 2004 Integrated List of Waters, as summarized in Table 1A.

Table 1A. The Pleasant Bay System Waterbody Segments in Category 5 of the Massachusetts 2002 and 2004 Integrated List[1]

NAME	WATERBODY SEGMENT	DESCRIPTION	SIZE	POLLUTANT LISTED
Pleasant Bay System				
Crows Pond	MA96-47_2002	To Bassing Harbor, Chatham	0.19 sq mi	-Nutrients
Frostfish Creek	MA96-49_2002	Outlet from cranberry bog northwest of Stony Hill Road to confluence with Ryder Cove, Chatham	0.02 sq mi	-Nutrients -Pathogens
Ryder Cove	MA96-50_2002	Chatham	0.17 sq mi	-Nutrients -Pathogens
Muddy Creek	MA96-51_2002	Outlet of small unnamed pond south of Countryside Drive and north-northeast of Old Queen Anne Road to mouth at Pleasant Bay, Chatham	0.05 sq mi	-Pathogens

[1] These segments are also classified as Category 5 on the Draft 2006 Integrated List.

A complete description of the system is presented in Chapters I and IV of the MEP Technical Report. A majority of the information on these subembayments is drawn from this report. Chapter VI and VII of the MEP Technical report provide assessment data on the individual waterbody segments listed in Table 1B (below). Please note that pathogens are listed in Tables 1A and 1B for completeness, further discussion of pathogens is beyond the scope of this TMDL.

The subembayments addressed by this document are determined to be high priorities based on 3 significant factors: (1) the initiative that the Towns have taken to assess the conditions of this entire embayment system, (2) the commitment made by the Town to restoring and preserving the subembayments, and (3) the extent of impairment in the subembayments. In particular, these subembayments are at risk of further degradation from increased N loads entering through groundwater and surface water from their increasingly developed watersheds. In both marine and freshwater systems, an excess of nutrients results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources. The general conditions related to the major indicators of habitat impairment, due to excess nutrient loadings, are summarized and tabulated in Table 1C. Where more than one listing of conditions is listed (ex. MI/SI) a gradient of increasing water quality is present sampling from the upper sub-embayment to the lower sub-embayment. This is due to the cleaner tidal flushing water from the Atlantic Ocean. Observations are summarized in the Problem Assessment section below, and detailed in Chapter VII of the MEP Technical Report.

Table 1B. Comparison of impaired parameters for the impaired subembayments within the Pleasant Bay System

NAME	DEP Listed Impaired Parameter	SMAST Listed Impaired Parameter
Pleasant Bay System		
Meetinghouse Pond & Outlet		-Nutrients -DO level -Chlorophyll -Macroalgae -Benthic fauna
Lonnies Pond		-Nutrients -DO level -Chlorophyll -Macroalgae -Benthic fauna
Areys Pond & Outlet		-Nutrients -DO level -Chlorophyll -Macroalgae -Benthic fauna
The River		-Nutrients -DO level -Chlorophyll -Macroalgae -Eelgrass loss\ - Benthic fauna
Paw Wah Pond		-Nutrients -DO level -Chlorophyll -Macroalgae -Benthic fauna
Quanset Pond		-Nutrients -DO level -Chlorophyll -Benthic fauna
Round Cove		-Nutrients -DO level -Chlorophyll -Benthic fauna
Muddy Creek Upper	-Pathogens	-Nutrients -DO level -Chlorophyll -Benthic fauna
Muddy Creek Lower	-Pathogens	-Nutrients -DO level -Chlorophyll -Eelgrass loss -Benthic fauna
Ryders Cove	-Nutrients -Pathogens	-Nutrients -Chlorophyll -Macroalgae -Eelgrass loss -Benthic fauna

Table 1B continued

Crows Pond	-Nutrients	-Nutrients -Chlorophyll -Macroalgae -Eelgrass loss -Benthic fauna
Bassing Harbor (Lower Basin)		-Nutrients -Chlorophyll -Eelgrass loss -Benthic fauna
Frost Fish Creek	-Nutrients -Pathogens	-Nutrients -Chlorophyll -Macroalgae -Benthic fauna
Pochet		-Nutrients -DO level -Benthic fauna
Little Pleasant Bay		-Nutrients -DO level -Eelgrass loss -Benthic fauna
Pleasant Bay		-Nutrients -DO level -Chlorophyll -Eelgrass loss -Benthic fauna

Figure 2 Overview of the Pleasant Bay System

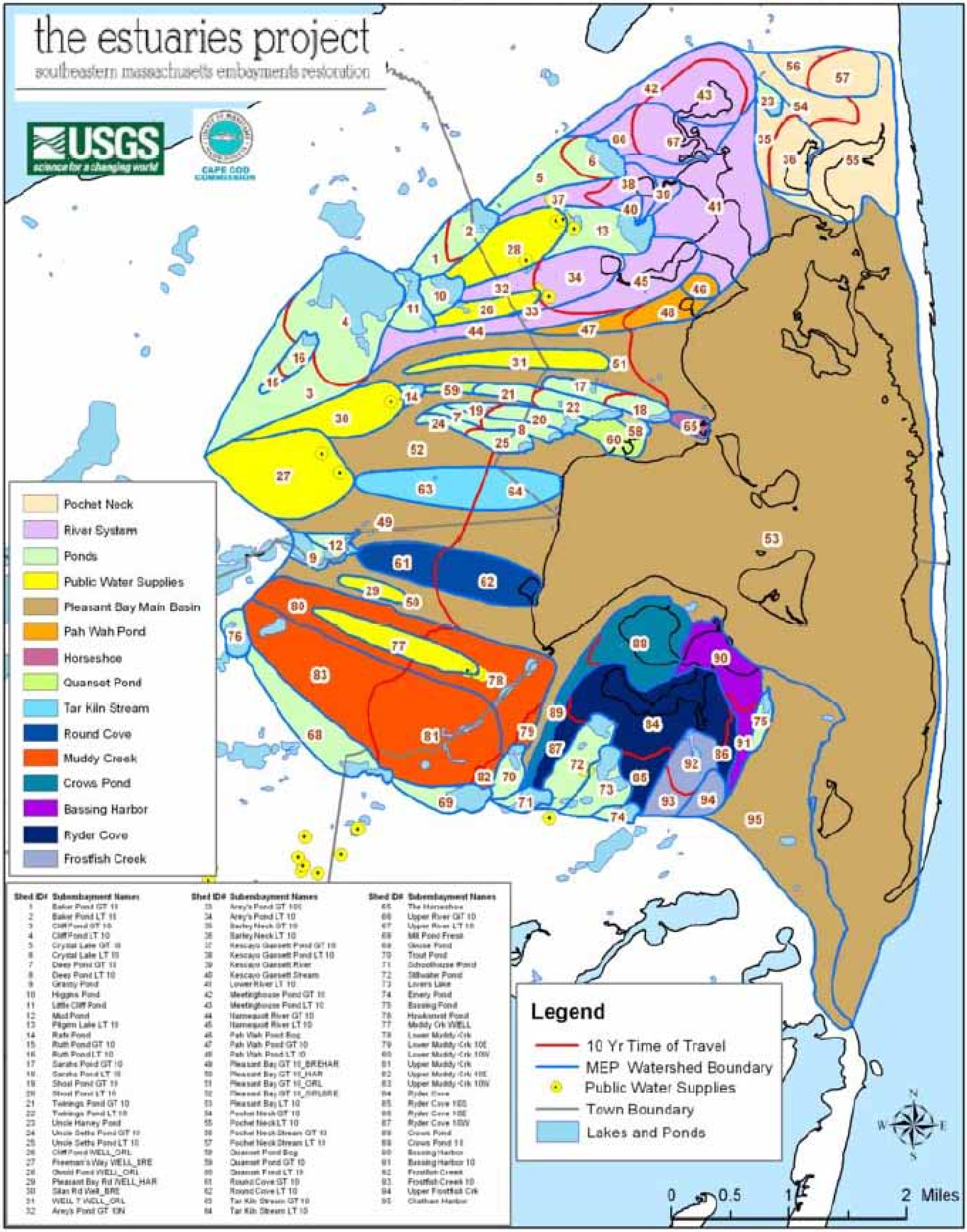


Figure 3 Pleasant Bay Subwatershed Delineation

Table 1C. General summary of conditions related to the major indicators of habitat impairment observed in the Pleasant Bay System.

Embayment/ Sub-embayment	Eelgrass Loss[1]	Dissolved Oxygen Depletion	Chlorophyll *a*[2]	Macro-algae	Benthic Fauna[3]
Pleasant Bay System					
Meetinghouse Pond	NS	<6 mg/L up to 98% of time <4 mg/L up to 72% of time SI/SD	>10ug/L up to 21% of time >20 ug/L up to 1% of time SI/MI	MI	SI
Lonnies Pond	NS	<6 mg/L up to 99% of time <4 mg/L up to 73% of time SI	>10ug/L up to 20% of time >20 ug/L up to 1% of time MI	MI	SI
Areys Pond	NS	<6 mg/L up to 87% of time <4 mg/L up to 76% of time SD	>10ug/L up to 50% of time >20 ug/L up to 14% of time SI	SI/SD	SD
The River	MI	MI/SI	MI	MI/SI	SI
Paw Wah Pond	NS	<6 mg/L up to 97% of time <4 mg/L up to 91% of time SD	SI	SI	SD
Quanset Pond	NS	<6 mg/L up to 48% of time <4 mg/L up to 18% of time SI	>10ug/L up to 37% of time >20 ug/L up to 1% of time SI	NO	SD
Round Cove	NS	<6 mg/L up to 13% of time <4 mg/L up to 1% of time MI	>10ug/L up to 48% of time >20 ug/L up to 1% of time SI	NO	SI
Muddy Creek Upper	NS	<6 mg/L up to 88% of time <4 mg/L up to 76% of time SI/SD	>10ug/L up to 91% of time >20 ug/L up to 67% of time SD	MI[4]	SD
Muddy Creek Lower	SI	<6 mg/L up to 85% of time <4 mg/L up to 60% of time SI/SD	>10ug/L up to 88% of time >20 ug/L up to 84% of time SI	MI[4]	SI
Ryders Cove	MI	<6 mg/L up to 73% of time <4 mg/L up to 7% of time SI/SD	>10ug/L up to 74% of time >20 ug/L up to 18% of time SI/MI	MI	MI
Crows Pond	MI	<6 mg/L up to 28% of time <4 mg/L 0% of time SI	>10ug/L up to 69% of time >20 ug/L up to 2% of time MI	MI	H/MI
Bassing Harbor Lower	H/MI	<6 mg/L up to 7% of time <4 mg/L 0% of time H	>10ug/L up to 23% of time >20 ug/L 0% of time MI	NO	MI
Frost Fish Creek	NS	SI	SI	SI	SI
Pochet	NS	H/MI	>10ug/L up to 4% of time >20 ug/L 0% of time H	NO	H/MI
Little Pleasant Bay	MI	MI	H	NO	MI
Pleasant Bay	MI/SI	<6 mg/L up to 29% of time <4 mg/L up to 4% of time MI	>10ug/L up to 4% of time >20 ug/L 0% of time MI	NO	MI/SI
Chatham Harbor	H	<6 mg/L up to 7% of time <4 mg/L 0% of time H	>10ug/L 0% of time >20 ug/L 0% of time H	NO	H

Footnotes and key to symbols/terms on following page

Table 1C Footnotes and key to symbols/terms

1 Based on comparison of present conditions to 1951 Survey data.
2 Algal blooms are consistent with chlorophyll *a* levels above 20ug/L
3 Based on observations of the types of species, number of species, and number of individuals
4 Observation by the Pleasant Bay Association

H – Healthy – healthy habitat conditions*
MI – Moderately Impaired – slight to reasonable change from normal conditions*
SI – Significantly Impaired- considerably and appreciably changed from normal conditions*
SD – Severely Degraded – critically or harshly changed from normal conditions*
NS - Non-supportive habitat. No eelgrass was present in 1951 Survey data.
NO – none observed during study period.
* - These terms are more fully described in MEP report “Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators” December 22, 2003 (http://www.mass.gov/dep/water/resources/esttmdls.htm).

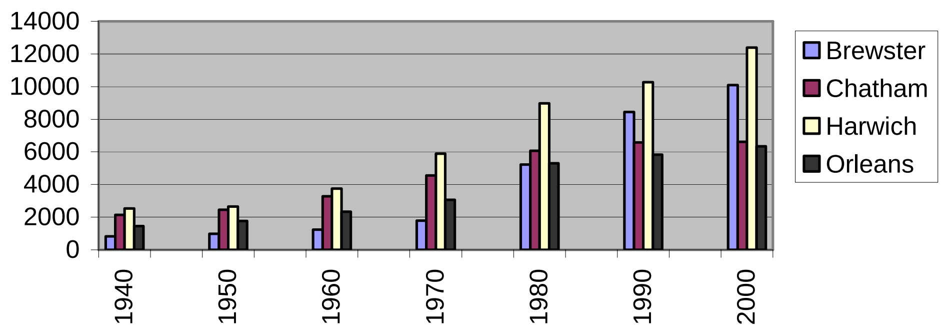
Problem Assessment

The watershed of Pleasant Bay system has all had rapid and extensive development of single-family homes and the conversion of seasonal into full time residences. This is reflected in a substantial transformation of land from forest to suburban use between the years 1950 to 2000. Water quality problems associated with this development result primarily from on-site wastewater treatment systems, and to a lesser extent, from runoff and fertilizers from these developed areas.

On-site subsurface wastewater disposal system effluents discharge to the ground, enter the groundwater system and eventually enter the surface water bodies. In the sandy soils of Cape Cod, effluent that has entered the groundwater travel towards the coastal waters at an average rate of one foot per day. The nutrient load to the groundwater system is directly related to the number of subsurface wastewater disposal systems, which in turn are related to the population. The population of Brewster, Chatham, Harwich, and Orleans as with all of Cape Cod, has increased markedly since 1950. In the period from 1950 to 2000 the number of year round residents has almost quadrupled. In addition, summertime residents and visitors swell the population of the entire Cape by about 300% according to the Cape Cod Commission (http://www.capecodcommission.org/data/trends98.htm#population).

The increase in year round residents is illustrated in the following figure:

Figure 3
Brewster, Chatham, Harwich, and Orleans Resident Population



Prior to the 1950's there were few homes and many of those were seasonal. During these times water quality was not a problem and eelgrass beds were plentiful. Dramatic declines in water quality, and the quality of the estuarine habitats, throughout Cape Cod, have paralleled its population growth since these times. The problems in these particular subembayments generally include periodic decreases of dissolved oxygen, decreased diversity of benthic animals, and periodic algal blooms. Eelgrass beds, which are critical habitats for macroinvertebrates and fish, have shown significant deterioration in these waters. Furthermore, the eelgrass can be replaced by macro algae, which are undesirable, because they do not provide high quality habitat for fish and invertebrates. In the most severe cases habitat degradation could lead to periodic fish kills, unpleasant odors and scums, and near loss of the benthic community and/or presence of only the most stress-tolerant species of benthic animals.

Coastal communities rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as commercial fin fishing and shellfishing. The continued degradation of these coastal subembayments, as described above, will significantly reduce the recreational and commercial value and use of these important environmental resources.

Habitat and water quality assessments were conducted on this system based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. This system displays a range of habitat quality. In general, the habitat quality of the subembayments studied is highest near the tidal inlet on the Atlantic Ocean and poorest in the inland-most tidal reaches. This is indicated by gradients of the various indicators. Nitrogen concentrations are highest inland and lowest near the mouths. Eelgrass has been significantly reduced from the original 1951 survey. The dissolved oxygen records showed significant diurnal swings in this system accompanied by elevated levels of chlorophyll *a* (above 20 ug/L). The benthic infauna study on this system showed the similar pattern of improvement increasing as the distance to the tidal inlets decreases. All the subembayments showed significant habitat impairment in the uppermost reaches with improvement to moderate habitat impairment approaching the inlets. Only in the Chatham Harbor and inlet area did habitat improve to moderately healthy near the tidal inlet.

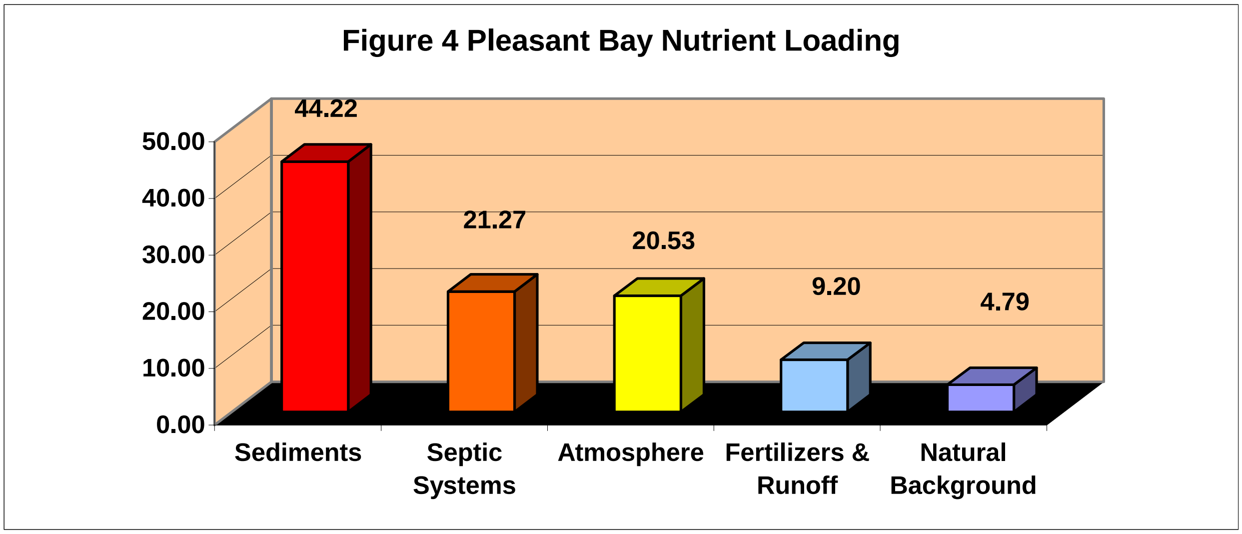
Pollutant of Concern, Sources, and Controllability

In this coastal system, as in most marine and coastal waters, the limiting nutrient is nitrogen. Nitrogen concentrations beyond those expected naturally contribute to undesirable conditions, including the severe impacts described above, through the promotion of excessive growth of plants and algae, including nuisance vegetation.

Each of the waterbody segments covered in this TMDL has had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the Towns of Brewster, Chatham, Harwich, and Orleans, the USGS, and the Cape Cod Commission. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report.

These investigations revealed that loadings of nutrients, especially N, are much larger than they would be under natural conditions, and as a result the water quality has deteriorated. A principal indicator of decline in water quality is the disappearance of eelgrass from a significant portion (up to 24% throughout the entire system) of its natural habitat in these subembayments. This is a result of nutrient loads causing excessive growth of algae in the water (phytoplankton) and algae growing on eel grass (epiphyton), both of which result in the loss of eelgrass through the reduction of available light levels.

As is illustrated by Figure 4, most of the N affecting this system originates from the sediments, on-site subsurface wastewater disposal systems (septic systems) and atmospheric deposition are the next largest sources. Considerably less N originates from fertilizers, runoff and natural background sources. Although this figure shows that overall the sediments are a large N source, examination of the sections of individual subembayments indicates that some of them have sediments that provide a significant sink of N (Table 3). Under certain environmental conditions sediments can denitrify, thus freeing up capacity in the sediments to absorb more nitrogen. Where the sediments result in N loading it should be emphasized that this is a result of N loading from other sources. As the N loading from other sources decreases, the sediment N loading will decrease.



The level of "controllability" of each source, however, varies widely:

Atmospheric nitrogen cannot be adequately controlled locally – it is only through region and nation-wide air pollution control initiatives that reductions are feasible;

Sediment nitrogen control by such measures as dredging is not feasible on a large scale. However, the concentrations of N in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document. Increased dissolved oxygen will help keep nitrogen from fluxing;

Fertilizer – related nitrogen loadings can be reduced through bylaws and public education;

Stormwater sources of N can be controlled by best management practices (BMPs), bylaws and stormwater infrastructure improvements;

Septic system sources of nitrogen are the largest controllable sources. These can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, upgrading/repairing failed systems, transporting and treating septage at treatment facilities with N removal technology either in or out of the watershed, or installing nitrogen-reducing on-site wastewater treatment systems.

Natural Background is the background load as if the entire watershed was still forested and contains no anthropogenic sources. It cannot be controlled locally.

Cost/benefit analyses will have to be conducted on all of the possible N loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

Description of the Applicable Water Quality Standards

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen, but have only narrative standards that relate to the other variables, as described below:

314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(c) states, "Nutrients – Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication".

314 CMR 4.05(b) 1:

(a) Class SA

1. Dissolved Oxygen -
a. Shall not be less than 6.0 mg/l unless background conditions are lower;
b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 75% of saturation due to a discharge; and
c. site-specific criteria may apply where background conditions are lower than specified levels or to the bottom stratified layer where the Department determines that designated uses are not impaired.

(b) Class SB

1. Dissolved Oxygen -
a. Shall not be less than 5.0 mg/L unless background conditions are lower;
b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 60% of saturation due to a discharge; and
c. site-specific criteria may apply where back-ground conditions are lower than specified levels or to the bottom stratified layer where the Department determines that designated uses are not impaired.

Thus, the assessment of eutrophication is based on site specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the US Environmental Protection Agency in their draft Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (EPA-822-B-01-003, Oct 2001). The Guidance Manual notes that lakes, reservoirs, streams, and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management. However, individual estuarine and coastal marine waters have unique characteristics, and development of individual water body criteria is typically required.

It is this framework, coupled with an extensive outreach effort that the Department, and technical support of SMAST, that MassDEP is employing to develop nutrient TMDLs for coastal waters.

Methodology - Linking Water Quality and Pollutant Sources

Extensive data collection and analyses have been described in detail in the MEP Technical Report. Those data were used by SMAST to assess the loading capacity of each sub-embayment. Physical (Chapter V), chemical and biological (Chapters IV, VII, and VIII**)** data were collected and evaluated. The primary water quality objective was represented by conditions that:

1) restore the natural distribution of eelgrass because it provides valuable habitat for shellfish and finfish
2) prevent algal blooms
3) protect benthic communities from impairment or loss
4) maintain dissolved oxygen concentrations that are protective of the estuarine communities.

The details of the data collection, modeling and evaluation are presented and discussed in Chapters IV, V, VI, VII and VIII of the MEP Technical Report. The main aspects of the data evaluation and modeling approach are summarized below, taken from pages 4 through 8 of that report.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and N characteristics, and is characterized as follows:

- requires site specific measurements within the watershed and each sub-embayment;
- uses realistic "best-estimates" of N loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- spatially distributes the watershed N loading to the embayment;
- accounts for N attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes N regenerated within the embayment;
- is validated by both independent hydrodynamic, N concentration, and ecological data;
- is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model has been applied previously to watershed N management in over 15 embayments throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated, and has use as a management tool for evaluating watershed N management options.

The Linked Model, when properly calibrated and validated for a given embayment, becomes a N management planning tool as described in the model overview below. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. In addition, since the Linked Model uses a holistic approach that incorporates the entire watershed, embayment and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries.

The Linked Model provides a quantitative approach for determining an embayments: (1) N sensitivity, (2) N threshold loading levels (TMDL) and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics (Figure I-2 of the MEP Technical Report). This methodology integrates a variety of field data and models, specifically:

• Monitoring - multi-year embayment nutrient sampling

• Hydrodynamics -

- embayment bathymetry (depth contours throughout the embayment)
- site specific tidal record (timing and height of tides)
- water velocity records (in complex systems only)
- hydrodynamic model

• Watershed Nitrogen Loading

- watershed delineation
- stream flow (Q) and N load
- land-use analysis (GIS)
- watershed N model

• Embayment TMDL - Synthesis

- linked Watershed-Embayment Nitrogen Model
- salinity surveys (for linked model validation)
- rate of N recycling within embayment
- dissolved oxygen record
- Macrophyte survey
- Infaunal survey (in complex systems)

Application of the Linked Watershed-Embayment Model

The approach developed by the MEP for applying the linked model to specific subembayments, for the purpose of developing target N loading rates, includes:

1) selecting one or two stations within each embayment system, located close to the inland-most reach or reaches, which typically has the poorest water quality within the system. These are called “sentinel” stations;

2) using site-specific information and a minimum of 3 years of sub-embayment-specific data to select target/threshold N concentrations for each sub-embayment. This is done by refining the draft threshold N concentrations that were developed as the initial step of the MEP process. The target concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

3) running the calibrated water quality model using different watershed N loading rates, to determine the loading rate which will achieve the target N concentration at the sentinel station. Differences between the modeled N load required to achieve the target N concentration, and the present watershed N load, represent N management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses, and the modeling activities described above, resulted in four major outputs that were critical to the development of the TMDLs. Two outputs are related to N **concentration**:

- the present N concentrations in the subembayments
- site-specific target (threshold) concentrations

and, two outputs are related to N **loadings:**

- the present N loads to the subembayments
- load reductions necessary to meet the site specific target N concentrations

A brief overview of each of the outputs follows:
<u>Nitrogen concentrations in the subembayments</u>

a) Observed "present" conditions:
Table 2 presents the average concentrations of N measured in this system from ten years of data collection (during the period 2000 through 2005). Concentrations of N are the highest in upper Muddy Creek (1.26 mg/L). Nitrogen in the other subembayments ranges in concentration from 0.23 to 1.16 mg/L, resulting in overall ecological habitat quality ranging from moderately high to poor. The individual station means and standard deviations of the averages are presented in Tables A-1 of Appendix A.

b) Modeled site-specific target threshold nitrogen concentrations:

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. Prior to conducting the analytical and modeling activities described above, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and N concentrations. The Linked Model was then used to determine site-specific threshold N concentrations by using the specific physical, chemical and biological characteristics of each sub-embayment.As listed in Table 2, the site-specific target (threshold) bioactive N concentrations for the sentinel stations listed range from 0.16 – 0.21 mg/L.

The findings of the analytical and modeling investigations for this embayment system are discussed and explained below:

The threshold nitrogen level for an embayment represents the average watercolumn concentration of nitrogen that will support the habitat quality being sought. The watercolumn nitrogen level is ultimately controlled by the integration of the watershed nitrogen load, the nitrogen concentration in the inflowing tidal waters (boundary condition) and dilution and flushing via tidal flows. The water column nitrogen concentration is modified by the extent of sediment regeneration and by direct atmospheric deposition.

Threshold N levels for each of the embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. In these systems, high habitat quality was defined as supportive of eelgrass and diverse benthic animal communities. Dissolved oxygen and chlorophyll *a* were also considered in the assessment. Overall N loads (Tables ES-1 and ES-2 of the MEP Technical Report) for the Pleasant Bay System were comprised primarily of benthic flux N and to a lesser degree the load from septic tanks and land use. Land-use and wastewater analysis found that overall 70% of the controllable N load to the embayments was from septic system effluent. This controllable load does not include atmospheric deposition or benthic flux.

Table 2. Observed present nitrogen concentrations and target threshold nitrogen concentrations derived for the Pleasant Bay System

Subembayments (Sentinel Stations are in bold)	Sub-embayment Observed Total Nitrogen Concentration [1] (mg/L)	Sub-embayment Observed Bioactive Nitrogen Concentration (mg/L)	Target Threshold Bioactive Nitrogen Concentrations (mg/L)
Meetinghouse Pd (WMO-10)	0.72-0.98[2]	0.28-0.41[2]	0.21
The River-upper (WMO-9)	0.86	0.25	0.20
The River-lower (PBA-13)	0.56	0.18	0.17
Lonnies Pond (PBA-15)	0.78	0.28	0.21
Areys Pond (PBA-14)	0.73	0.30	0.25
Namequoit River (WMO-06)	0.73-0.83[2]	0.24-0.30[2]	0.21
The River-mid (WMO-08)	0.85	0.18	0.18
Pochet Neck (WMO-05)	0.72-0.84[2]	0.24-0.28[2]	0.21
Little Pleasant Bay (PBA-12)	0.57-0.77[2]	0.14-0.18[2]	0.16
Paw Wah Pond (PBA-11)	0.71	0.27	0.21
Quanset Pond (WMO-12)	0.56-0.60[2]	0.19-0.21[2]	0.21
Round Cove (PBA-09)	0.71	0.25	0.21
Muddy Creek-upper (PBA-05a)	1.26	0.70	0.41
Muddy Creek-lower (PBA-05)	0.57	0.24	0.21
Pleasant Bay	0.44-0.73[2]	0.14-0.19[2]	0.16
Ryders Cove (PBA-03)	0.42-0.72[2]	0.16-0.25[2]	0.16
Frost Fish Creek-lower (M-14)	1.16	0.35	0.17
Crows Pond (PBA-04)	0.84	0.21	0.15
Bassing Harbor (PBA-022)	0.49	0.12	0.12
Chatham Hbr – upper (PBA-01)	0.35-0.43[2]	0.10-0.11[2]	0.10
Atlantic Ocean (Boundary Condition)		0.09	

[1] calculated as the average of the separate yearly means of 2000-2005 data. Overall means and standard deviations of the average are presented in Tables A-1 Appendix A
[2] listed as a range since it was sampled as several segments (see Table A-1 Appendix A)

A major finding of the MEP clearly indicates that a single total nitrogen threshold can not be applied to Massachusetts' estuaries, based upon the results of the Popponesset Bay System, the Hamblin / Jehu Pond / Quashnet River analysis in eastern Waquoit Bay. This is almost certainly going to be true for the other embayments within the MEP area, as well.

The threshold nitrogen levels for the Pleasant Bay System were determined as follows:

Pleasant Bay Threshold Nitrogen Concentrations

While there is significant variation in the dissolved organic nitrogen levels, hence total nitrogen levels supportive of healthy eelgrass habitat, the level of bioactive nitrogen supportive of this habitat appears to be relatively constant. Therefore, the MEP Technical Team set a single eelgrass threshold based upon stable eelgrass beds, tidally averaged bioactive N levels and the stability of eelgrass as depicted in coverage from 1951-2001. The eelgrass threshold was set at 0.16 mg/L bioactive N based upon the Chatham (Dec 2003 MEP report) analysis for Bassing Harbor. That report for Bassing Harbor indicated a bioactive level for high quality eelgrass habitat of 0.160 mg/L bioactive N based upon Healthy eelgrass community in both Bassing Harbor at 0.135 mg/L bioactive N and in Stage Harbor at 0.160 mg/L bioactive N (Oyster River Mouth). The higher value was used as the eelgrass habitat in Bassing Harbor was below its nitrogen loading limit at that time. Taking into consideration the analysis of the Pleasant Bay System, the bioactive nitrogen threshold of 0.160

mg/L N yields an equivalent Total Nitrogen Threshold for the Bassing Harbor subembayment (average upper and lower Ryders Cove stations) of 0.523 mg/L N. This value is very close to the previous Bassing Harbor specific threshold range of 0.527-0.552 mg/L N. The slight shift in threshold level results from the greatly expanded water quality database for the present versus previous analysis. The nitrogen boundary condition (concentration of N in inflowing tidal waters from Pleasant Bay) for the Bassing Harbor System is 0.45 mg/L N.

The sentinel station for the Pleasant Bay System based on a nitrogen threshold targeting restoration of eelgrass was placed within the uppermost reach of Little Pleasant Bay (PBA-12) near the inlets to The River and Pochet. The threshold bioactive nitrogen level at this site (as for Ryders Cove) is 0.160 mg/L bioactive N. Based upon the background dissolved organic nitrogen average of upper Little Pleasant Bay and Lower Pochet 0.563 mg/L N and the bioactive threshold value, the total nitrogen level at the sentinel station (PBA-12) is 0.723 mg/L N. The restoration goal is to improve the eelgrass habitat throughout Little Pleasant Bay and the historic distribution in Pleasant Bay, which will see lower nitrogen levels when the threshold is reached. In addition, the fringing eelgrass beds within The River and within Pochet should also be restored, as they are in shallower water than the nearby sentinel site and therefore are able to tolerate slightly higher watercolumn nitrogen levels. Moreover, the same threshold bioactive nitrogen level should be met for the previous sentinel station (upper Ryders Cove) in Bassing Harbor System when levels are achieved at the sentinel station in upper Little Pleasant Bay. However, given the partial independence of the Bassing Harbor sub-embayment system relative to the greater Pleasant Bay System (i.e. its own local watershed nitrogen load plays a critical role in its health), the upper Ryders Cove sentinel station should be maintained as the guide for this sub-embayment to Pleasant Bay. It should also be noted that while the bioactive threshold is the same at both sites, the Total Nitrogen level in Ryders Cove is 0.523 mg/L N, due to the lower dissolved organic nitrogen levels in the lower Bay.

While eelgrass restoration is primary nitrogen management goal within the Pleasant Bay System, there are small basins which do not appear to have historically (1951) supported eelgrass habitat. For these sub-embayments, restoration and maintenance of healthy animal communities is the management goal. At present, moderately impaired infaunal communities are present in Ryders Cove (PBA-03) at tidally averaged bioactive nitrogen levels of 0.244 mg/L N. Similarly, there are moderately impaired infaunal communities, designated primarily by the dominance of amphipods (amphipod mats) in most of the 8 sub-embayments of focus. These communities are present adjacent the inlet to Lonnies Pond (in The River Upper) at bioactive nitrogen levels of 0.217 mg/L N, in the Namequoit River at 0.216-0.239 mg/L N and in Round Cove at mg/L N at 0.239 mg/L N. These communities can be found at even higher levels in the fringing shallow areas of deep basins like Areys Pond (0.299 mg/L N) and Meetinghouse Pond (0.411 mg/L N). Very shallow waters tend to minimize oxygen depletion that severely stress infaunal communities in deeper basins. Paw Wah Pond is periodically hypoxic and as a result does not presently support infaunal habitat. These data are at higher bioactive nitrogen levels than the healthy infaunal habitat in the lower Pochet Basin (WMO-03) at 0.178 mg/L N. It appears that the infaunal threshold lies between 0.18 and 0.22 mg/L N tidally averaged bioactive nitrogen. Based upon the animal community and nitrogen analysis discussed in Chapter VIII, the restoration goal for the 8 small tributary sub-basin systems to Pleasant Bay is to restore a healthy habitat to the full basin in the shallower or more open waters and to the margins in the deep drowned kettles that periodically stratify. This would argue for a bioactive nitrogen threshold of 0.21 mg/L N, lower than the lowest station with significant amphipod presence. Translation to Total Nitrogen is presented in detail in Chapter VIII.

Development of nitrogen load reductions needed to meet the threshold concentration of 0.16 mg/l bioactive nitrogen (DIN+PON) in Ryders Cove (the average of PBA-03 and CM-13) and Upper Little Pleasant Bay (PBA-13) focused primarily on septic load removal within the River and Bassing Harbor systems. Due to the relatively large size of the Pleasant Bay system, achieving the primary threshold concentration for the restoration of eelgrass at the sentinel stations alone did not achieve the secondary threshold at the series of small embayments surrounding Pleasant and Little Pleasant Bays. The secondary threshold concentration of 0.21 mg/l bioactive nitrogen (DIN+PON) in Meetinghouse Pond (Outer), Lonnies Pond, Upper Namequoit River, Upper Pochet, Paw Wah Pond, Little Quanset Pound, Round Cove and Lower Muddy Creek required site-specific removal of septic nitrogen from the watersheds directly impacting these sub-embayments. Chapter VIII of the MEP Technical Report presents the percent of septic load removed from the various watersheds to achieve both the primary and secondary threshold concentrations of bioactive nitrogen at the sentinel stations

It is important to note that the analysis of future nitrogen loading to the Pleasant Bay estuarine system focuses upon additional shifts in land-use from forest/grasslands to residential and commercial development. However, the MEP analysis indicates that significant increases in nitrogen loading can occur under present land-uses, due to shifts in occupancy, shifts from seasonal to year-round useage and increasing use of fertilizers (presently less than half of the parcels use lawn fertilizers). Therefore, watershed-estuarine nitrogen management must include management approaches to prevent increased nitrogen loading from both shifts in land-uses (new sources) and from loading increases of current land-uses. The overarching conclusion of the MEP analysis of the Pleasant Bay estuarine system is that restoration will necessitate a reduction in the present nitrogen inputs and management options to negate additional future nitrogen inputs.

<u>Nitrogen loadings to the subembayments</u>

a) Present loading rates:

In the Pleasant Bay System overall, the highest N loading from controllable sources is from on-site wastewater treatment systems. On-site septic system loadings range from 0.78 kg/day in Areys Pond to as high as 14.87 kg/day in Pleasant Bay. Nitrogen loading from the nutrient-rich sediments (referred to as benthic flux) is significant in these embayments. As discussed previously, however, the direct control of N from sediments is not considered feasible. However, the magnitude of the benthic contribution is related to the watershed load. Therefore, reducing the incoming load should reduce the benthic flux over time. The total N loading from all sources ranges from 2.74 kg/day in Bassing Harbor to 175.11 kg/day in the Pleasant Bay. A further breakdown of N loading, by source, is presented in Table 3. The data on which Table 3 is based can be found in Table ES-1 of the MEP Technical Report.

b) Nitrogen loads necessary for meeting the site-specific target nitrogen concentrations.

As previously indicated, the present N loadings to the Pleasant Bay System must be reduced in order to restore conditions and to avoid further nutrient-related adverse environmental impacts. The critical final step in the development of the TMDL is modeling and analysis to determine the loadings required to achieve the target N concentrations. Table 4 lists the present controllable watershed N loadings from the Pleasant Bay system. The last two columns indicate one scenario of the reduced sub-watershed loads and percentage reductions that could achieve the target concentrations in the sentinel systems (see following section). It is very important to note that load reductions can be produced through reduction of any or all sources of N, potentially increasing the natural attenuation of nitrogen within the freshwater systems to the system, and/or modifying the tidal flushing through inlet reconfiguration (where appropriate). The load reductions presented below represent only one of a suite of potential reduction approaches that need to be evaluated by the communities involved. The presentation of load reductions in Table 4 is to establish the general degree and spatial pattern of reduction that will be required for restoration of these N impaired embayments The loadings presented in Table 4 represent one, but not the only, loading reduction scenario that can meet the TMDL goal. This table looks at reducing both controllable land use and septic system loads. Other alternatives may also achieve the desired threshold concentration as well and can be explored using the MEP modeling approach. In the scenario presented, the percentage reductions in N loadings to meet threshold concentrations range from 100% in the Meetinghouse Pond and Muddy Creek – lower subembayments to 0 % in the Horseshoe, Crows Pond, Bassing

Table 3. Nitrogen loadings to the Pleasant Bay system from within the watersheds (natural background,

land use-related runoff, and septic systems), from the atmosphere, and from nutrient-rich sediments within the embayments.

Pleasant Bay System Subembayments	Present Land Use Load [1] (kg/day)	Present Septic System Load (kg/day)	Present Atmospheric Deposition (kg/day)	Present Benthic Input [2] (kg/day)	Total nitrogen load from all sources (kg/day)
Meetinghouse Pond	1.06	5.14	0.58	14.37	21.15
The River – upper	0.70	2.07	0.29	6.26	9.32
The River – lower	1.01	2.87	2.24	10.48	16.60
Lonnies Pond	0.81	1.63	0.23	1.59	4.26
Areys Pond	0.53	0.78	0.18	6.00	7.49
Namequoit River	0.73	2.01	0.52	14.57	17.83
Paw Wah Pond	0.35	1.51	0.08	3.63	5.57
Pochet Neck	1.81	6.61	1.77	0	10.19
Little Pleasant Bay	3.15	4.99	24.09	37.23	69.46
Quanset Pond	0.38	1.40	0.17	5.99	7.94
Round Cove	1.06	3.16	0.17	8.42	12.81
Muddy Creek – upper	2.83	7.16	0.16	4.56	14.71
Muddy Creek – lower	2.14	6.34	0.21	0	8.69
Pleasant Bay	14.41	14.87	37.01	108.82	175.11
Ryder Cove	2.68	7.14	1.30	9.36	20.48
Frost Fish Creek	0.70	2.20	0.10	0	3.00
Crows Pond	0.89	3.33	1.39	0.61	6.22
Bassing Harbor	0.27	1.40	1.07	0	2.74
Chatham Harbor	2.90	14.20	14.15	0	31.25
System Total	38.41	88.81	85.71	231.89	444.82

[1] composed of fertilizer and runoff and atmospheric deposition to lakes
[2] nitrogen loading from the sediments, negative fluxes have been set to zero

Harbor, and Chatham Harbor subembayments. Table VIII-3 of the MEP Technical Report (and rewritten as Appendix B of this document) summarizes the present loadings from on-site subsurface wastewater disposal systems and the reduced loads that would be necessary to achieve the threshold N concentrations in the Pleasant Bay system, under the scenario modeled here. In this scenario only the on-site subsurface wastewater disposal system loads were reduced to the level of the target threshold watershed load.

It should be emphasized once again that this is only one scenario that will meet the target N concentrations at the sentinel stations, which is the ultimate goal of the TMDL. There can be variations depending on the chosen sub-watershed and which controllable source is selected for reduction. Alternate scenarios will result in different amounts of nitrogen being reduced in different sub-watersheds. For example, taking out additional nitrogen upstream will impact how much nitrogen has to be taken out downstream. The towns involved should take any reasonable effort to reduce the controllable nitrogen sources.

Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a water body for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. The TMDLs are established to protect and/or

Table 4. Present Controllable Watershed nitrogen loading rates, calculated loading rates that are necessary to achieve target threshold nitrogen concentrations, and the percent reductions of the existing loads necessary to achieve the target threshold loadings.

Subembayments	Present controllable watershed load [1] (kg/day)	Target threshold watershed load[2] (kg/day)	Percent controllable watershed load reductions needed to achieve threshold loads
Meetinghouse Pond	6.20	1.06	82.9
The River – upper	2.77	1.74	37.2
The River – lower	3.88	2.44	37.1
Lonnies Pond	2.44	1.63	33.2
Areys Pond	1.30	0.92	29.2
Namequoit River	2.74	1.73	36.9
Paw Wah Pond	1.86	0.73	60.8
Pochet Neck	8.42	4.12	51.1
Little Pleasant Bay	8.13	5.88	27.7
Quanset Pond	1.78	1.08	39.3
Round Cove	4.23	2.96	30.0
Muddy Creek – upper	9.98	4.61	53.8
Muddy Creek – lower	8.48	2.14	74.8
Pleasant Bay	29.28	21.85	25.4
Ryder Cove	9.82	4.47	54.5
Frost Fish Creek	2.90	0.70	75.9
Crows Pond	4.22	4.22	0
Bassing Harbor	1.67	1.67	0
Chatham Harbor	17.10	17.10	0
System Total	127.20	81.25	36.12

[1] Composed of combined controllable land use and septic system loadings
[2] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold N concentrations identified in Table 2 above and derived from data found in Table ES2 of the Tech Report

restore the estuarine ecosystem, including eelgrass, the leading indicator of ecological health, thus meeting water quality goals for aquatic life support. Because there are no "numerical" water quality standards for N, the TMDLs for the Pleasant Bay System are aimed at determining the loads that would correspond to sub-embayment-specific N concentrations determined to be protective of the water quality and ecosystems.

The effort includes detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time), for each sub-embayment. The results of the mathematical model are correlated with estimates of impacts on water quality, including negative impacts on eelgrass (the primary indicator), as well as dissolved oxygen, chlorophyll, and benthic infauna

The TMDL can be defined by the equation:

$$TMDL = BG + WLAs + LAs + MOS$$

Where

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
LAs = portion allotted to (cultural) non-point sources
MOS = margin of safety

Background Loading

Natural background N loading estimates are presented in Table 3 above. Background loading was calculated on the assumption that the entire watershed is forested, with no anthropogenic sources of N.

Wasteload Allocations

Wasteload allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of storm water be included in the waste load component of the TMDL. On Cape Cod the vast majority of storm water percolates into the ground and aquifer and proceeds into the embayment systems through groundwater migration. The Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source – combining the assessments of waste water and storm water (including storm water that infiltrates into the soil and direct discharge pipes into water bodies) for the purpose of developing control strategies. Although the vast majority of storm water percolates into the ground, there are a few storm water pipes that discharge directly to water bodies that are subject to the requirements of the Phase II Storm Water NPDES Program. Therefore, any storm water discharges subject to the requirements of storm water Phase II NPDES permit must be treated as a waste load allocation. Since the majority of the nitrogen loading comes from septic systems, fertilizer and storm water that infiltrates into the groundwater, the allocation of nitrogen for any storm water pipes that discharge directly to any of the embayments is insignificant as compared to the overall groundwater load. Based on land use, the Linked Model accounts for loading for storm water, but does not differentiate storm water into a load and waste load allocation. Nonetheless, based on the fact that there are few storm water discharge pipes within NPDES Phase II communities that discharge directly to embayments or waters that are connected to the embayments, the total waste load allocation for these sources is considered to be insignificant (0.27% of the total load or 508.17 kg/year) as compared to the overall nitrogen load (83,198 kg/year total N load) to the embayments. Looking at individual subembayments this load ranged from 0.01-3.29% compared to the individual nitrogen load to each sub-embayment (Appendix C). This is based on the percent of impervious surface within 200 feet of the waterbodies and the relative load from this area compared to the overall load. Although most stormwater infiltrates into the ground on Cape Cod, some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of calculating this possible waste load allocation it was assumed that all impervious surfaces within 200 feet of the shoreline discharge directly to the waterbody. This load is obviously negligible when compared to other sources.

EPA policy also requires that stormwater regulated under the NPDES program be identified and included as a wasteload allocation. As discussed below, for the purpose of this TMDL, stormwater loadings are not differentiated into point and non-point sources.

EPA and MassDEP authorized the Towns of Brewster, Chatham, Harwich, and Orleans for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. The watershed of the embayment studied that is in Harwich is located in an area subject to the requirements of the permit, as EPA has mapped these entire areas of the watershed as regulated areas. EPA did not designate the entire watershed area in Brewster, Chatham, and Orleans as a regulated urbanized area. While communities need to comply with the Phase II permit only in the mapped Urbanized Areas, the Towns of Chatham and Orleans have decided to extend all the stormwater permit requirements throughout the entire area of both town, including this watershed area. Brewster currently is not planning on doing the same and is leaving the designated area in the town as set by EPA.

The Phase II general permit requires the permittee to determine whether the approved TMDL is for a pollutant likely to be found in storm water discharges from the MS4. The MS4 is required to implement the storm water waste load allocation, BMP recommendations or other performance requirements of a TMDL and assess whether the waste load allocation is being met through implementation of existing stormwater control measures or if additional control measures are necessary.

Load Allocations

Load allocations identify the portion of the loading capacity allocated to existing and future nonpoint sources. In the case of the Pleasant Bay system, the nonpoint source loadings are primarily from on-site subsurface wastewater disposal systems. Additional N sources include: natural background, stormwater runoff (including N from fertilizers), atmospheric deposition, and nutrient-rich sediments

Generally, stormwater that is subject to the EPA Phase II Program would be considered a part of the wasteload allocation, rather than the load allocation. As presented in Chapter IV, V, and VI, of the MEP Technical Report, on Cape Cod the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater. Given this, the TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and storm water for the purpose of developing control strategies. Ultimately, when the Phase II Program is implemented in Brewster, Chatham, Harwich, and Orleans new studies, and possibly further modeling, will identify what portion of the stormwater load may be controllable through the application of Best Management Practices (BMPs).

The sediment loading rates incorporated into the TMDL are lower than the existing sediment flux rates listed in Table 3 above because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments, and therefore, over time, reductions in loadings from the sediments will occur. Benthic N flux is a function of N loading and particulate organic nitrogen (PON). Projected benthic fluxes are based upon projected PON concentrations and watershed N loads, and are calculated by multiplying the present N flux by the ratio of projected PON to present PON, using the following formulae:

Projected N flux = (present N flux) (PON projected / PON present)

When: $\text{PON projected} = (R_{load})\,(D_{PON}) + \text{PON}_{\text{present offshore}}$

When $R_{load} = \text{(projected N load) / (Present N load)}$

And D_{PON} is the PON concentration above background determined by:

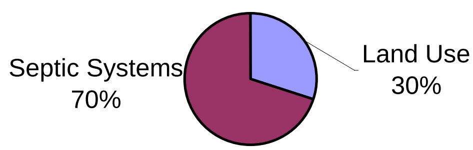
$$D_{PON} = (\text{PON}_{\text{present embayment}} - \text{PON}_{\text{present offshore}})$$

The benthic flux modeled for the Pleasant Bay system is reduced from existing conditions based on the load reduction and the observed PON concentrations within each sub-embayment relative to the Atlantic Ocean (boundary condition). The benthic flux input to each sub-embayment was reduced (toward zero) based on the reduction of N in the watershed load.

The loadings from atmospheric sources incorporated into the TMDL, however, are the same rates presently occurring, because, as discussed above, local control of atmospheric loadings is not considered feasible.

Locally controllable sources of N within the watersheds are categorized as on-site subsurface wastewater disposal system wastes and land use (which includes stormwater runoff and fertilizers). The following figure emphasizes the fact that the overwhelming majority of locally controllable N comes from on-site subsurface wastewater disposal systems.

Figure 5
Pleasant Bay System
Controllable Nitrogen Sources



Margin of Safety

Statutes and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA para 303 (d)(20©, 40C.G.R. para 130.7©(1)]. The EPA’s 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. The MOS for the Great, Green, and Bournes Embayment Systems TMDL is implicit, and the conservative assumptions in the analyses that account for the MOS are described below.

<u>1. Use of conservative data in the linked model</u>

The watershed N model provides conservative estimates of N loads to the embayments. Nitrogen transfer through direct groundwater discharge to estuarine waters is based upon studies indicating negligible aquifer attenuation, i.e. 100% of load enters embayment. This is a conservative estimate of loading because studies have also shown that in some areas less than 100% of the load enters the estuary. Nitrogen from the upper watershed regions, which travel through ponds or wetlands, almost always enter the embayment via stream flow, are directly measured (over 12-16 months) to determine attenuation. In these cases the land-use model has shown a slightly higher predicted N load than the measured discharges in the streams/rivers, which have been assessed to date. Therefore, the watershed model as applied to the surface water watershed areas again presents a conservative estimate of N loads because the actual measured N in streams was lower than the modeled concentrations.

The hydrodynamic and water quality models have been assessed directly. In the many instances where the hydrodynamic model predictions of volumetric exchange (flushing) have also been directly measured by field measurements of instantaneous discharge, the agreement between modeled and observed values has been $\geq$95%. Field measurement of instantaneous discharge was performed using acoustic doppler current profilers (ADCP) at key locations within the embayment (with regards to the water quality model, it was possible to conduct a quantitative assessment of the model results as fitted to a baseline dataset - a least squares fit of the modeled versus observed data showed an $R^2>0.95$, indicating that the model accounted for 95% of the variation in the field data). Since the water quality model incorporates all of the outputs from the other models, this excellent fit indicates a high degree of certainty in the final result. The high level of accuracy of the model provides a high degree of confidence in the output; therefore, less of a margin of safety is required.

In the case of N attenuation by freshwater ponds, attenuation was derived from measured N concentrations, pond delineations and pond bathymetry. These attenuation factors were higher than that used in the land-use model. The reason was that the pond data were temporally limited and a more conservative value of 50% was more protective and defensible.

In the case of the nitrogen load assessed to lawn fertilization rates for residential lawns, based on an actual survey, it is likely that this represents a conservative estimate of the nitrogen load. This too makes a more conservative margin of safety.

The nitrogen loading calculations are based on a wastewater engineering assumption that 90% of water use is converted to wastewater. Actual water use and conversion studies in the area have shown that this conversion rate is conservative adding to the margin of safety.

The nitrogen loading calculations for homes, which do not have metered water use, are based on a conservative estimate of water use compared to actual water use in the metered sections of the watershed. This adds to the margin of safety.

Similarly, the water column N validation dataset was also conservative. The model is water column N. However, the model predicts average summer N concentrations. The very high or low measurements are marked as outliers. The effect is to make the N threshold more accurate and scientifically defensible. If a single measurement 2 times higher than the next highest data point in the series raises the average 0.05 mg N/L, this would allow for a higher "acceptable" load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the N threshold for a system. This effectively strengthens the data set so that a higher margin of safety is not required.

Finally, the reductions in benthic regeneration of N are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of PON, due to lower primary production rates under the reduced N loading in these systems. As the N loading decreases and organic inputs are reduced, it is likely that rates of coupled remineralization-nitrification, denitrification and sediment oxidation will increase.

Benthic regeneration of N is dependant upon the amount of PON deposited to the sediments and the percentage that is regenerated to the water column versus being denitrified or buried. The regeneration rate projected under reduced N loading conditions was based upon two assumptions:(1) PON in the embayment in excess of that of inflowing tidal water (boundary condition) results from production supported by watershed N inputs and (2) Presently enhanced production will decrease in proportion to the reduction in the sum of watershed N inputs and direct atmospheric N input. The latter condition would result in equal embayment versus boundary condition production and PON levels if watershed N loading and direct atmospheric deposition could be reduced to zero (an impossibility of course). This proportional reduction assumes that the proportion of remineralized N will be the same as under present conditions, which is almost certainly an underestimate. As a result, future N regeneration rates are overestimated which adds to the margin of safety.

2. Conservative threshold sites/nitrogen concentrations

Conservatism was used in the selection of the threshold sites and N concentrations. Sites were chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher N concentrations. Meeting the target thresholds in the sentinel subembayments will result in reductions of N concentrations in the rest of the systems.

3 Conservative approach

The target loads were based on tidal averaged N concentrations on the outgoing tide, which is the worst case condition because that is when the N concentrations are the highest. The N concentrations will be lower on the flood tides therefore this approach is conservative.

In addition to the margin of safety within the context of setting the N threshold levels, described above, a programmatic margin of safety also derives from continued monitoring of these subembayments to support adaptive management. This continuous monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the N management plan. This will allow refinements to the plan to ensure that the desired level of restoration is achieved.

Seasonal Variation

Since the TMDLs for the waterbody segments are based on the most critical time period, i.e. the summer growing season, the TMDLs are protective for all seasons. The daily loads can be converted to annual loads by multiplying by 365 (the number of days in a year). Nutrient loads to the subembayments are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Second, as a practical matter, the types of controls necessary to control the N load, the nutrient of primary concern, by their very nature do not lend themselves to intra-annual manipulation since the majority of the N is from non-point sources. Thus, the annual loads make sense, since it is difficult to control non-point sources of nitrogen on a seasonal basis and that nitrogen sources can take considerable time to migrate to impacted waters.

TMDL Values for Pleasant Bay Systems

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of each sub-embayment were calculated by considering all sources of N grouped by natural background, point sources, and non-point sources. A more meaningful way of presenting the loadings data, from an implementation perspective, is presented in Table 5. In this table the N loadings from the atmosphere and nutrient-rich sediments are listed separately from the target watershed threshold loads, which are composed of natural background N along with locally controllable N from the on-site subsurface wastewater disposal systems, stormwater runoff, and fertilizer sources. In the case of the Pleasant Bay system the TMDLs were calculated by projecting reductions in locally controllable on-site subsurface wastewater disposal system, stormwater runoff, and fertilizer sources. Once again the goal of this TMDL is to achieve the identified N threshold concentration in the identified sentinel system. The target load identified in this table represents one alternative loading scenario to achieve that goal but other scenarios may be possible and approvable as well.

Table 5. The Total Maximum Daily Loads (TMDL) for the Pleasant Bay System, represented as the sum of the calculated target thresholds loads (from controllable watershed sources), atmospheric deposition, and sediment sources (benthic input).

Sub-embayment	Target Threshold Watershed Load [1] (kg/day)	Atmospheric Deposition (kg/day)	Benthic Input [2] (kg/day)	TMDL [3] (kg/day)
Meetinghouse Pond	1.06	0.58	7.86	9.50
The River – upper	1.74	0.29	4.10	6.13
The River – lower	2.44	2.24	8.52	13.2
Lonnies Pond	1.63	0.23	1.30	3.16
Areys Pond	0.92	0.18	4.93	6.03
Namequoit Pond	1.73	0.52	12.23	14.47
Paw Wah Pond	0.73	0.08	2.67	3.48
Pochet Neck	4.12	1.77	0	5.89
Little Pleasant Bay	5.88	24.09	35.22	65.19
Quanset Pond	1.08	0.17	4.79	6.04
Round Cove	2.96	0.17	6.74	9.87
Muddy Creek – upper	4.61	0.16	2.70	7.47
Muddy Creek – lower	2.14	0.21	0	2.35
Pleasant Bay	21.85	37.01	96.17	155.03
Ryder Cove	4.47	1.30	6.71	12.48
Frost Fish Creek	0.70	0.10	0	0.71
Crows Pond	4.22	1.39	0.61	6.22
Bassing Harbor	1.67	1.07	0	2.74
Chatham Harbor	17.10	14.15	0	31.25
System Total	81.25	85.71	194.55	361.51

[1] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 2.
[2] Projected sediment N loadings obtained by reducing the present loading rates (Table 3) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON. Negative benthic fluxes have been reset to zero, as they are not a load.
[3] The sum of target threshold watershed load, atmospheric deposition load, and benthic input load.

Implementation Plans

The critical element of this TMDL process is achieving the sub-embayment specific N concentrations presented in Table 2 above, that are necessary for the restoration and protection of water quality and eelgrass habitat within the Pleasant Bay system. In order to achieve those target concentrations, N loading rates must be reduced throughout this system. Table 5, above, is based on Table ES-2 of the MEP Technical Report. It lists target watershed threshold loads for each sub-embayment. If those threshold loads are achieved, this system will be protected.

As previously noted, this loading reduction scenario is not the only way to achieve the target N concentrations. The Towns are free to explore other loading reduction scenarios through additional modeling as part of the Comprehensive Wastewater Management Plan (CWMP). It must be demonstrated, however, that any alternative implementation strategies will be protective of the overall Pleasant Bay, and that none of the subembayments will be negatively impacted. To this end, additional linked model runs can be performed by the MEP at a nominal cost to assist the planning efforts of the Towns in achieving target N loads that will result in the desired threshold concentrations. The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the MassDEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results.

Because the vast majority of controllable N load is from individual on-site subsurface wastewater disposal systems for private residences, the CWMP should assess the most cost-effective options for achieving the target N watershed loads, including but not limited to, sewering and treatment for N control of sewage and septage at either centralized or de-centralized locations, and denitrifying systems for all private residences.

The Towns, however, are urged to meet the target threshold N concentrations by reducing N loadings from any and all sources, through whatever means are available and practical, including reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater BMPs, in addition to reductions in on-site subsurface wastewater disposal system loadings.

DEP's MEP Implementation Guidance report (http://www.mass.gov/dep/water/resources/restore.htm) provides N loading reduction strategies that are available to the Towns of Brewster, Chatham, Harwich, and Orleans that could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- Wastewater Treatment
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment
    - Community Treatment Plants
    - Municipal Treatment Plants and Sewers
- Tidal Flushing
    - Channel Dredging
    - Inlet Alteration
    - Culvert Design and Improvements
- Stormwater Control and Treatment *
    - Source Control and Pollution Prevention
    - Stormwater Treatment
- Attenuation via Wetlands and Ponds
- Water Conservation and Water Reuse
- Management Districts
- Land Use Planning and Controls
    - Smart Growth
    - Open Space Acquisition
    - Zoning and Related Tools
- Nutrient Trading

* The Towns of Brewster, Chatham, Harwich, and Orleans are four of the 237 communities in Massachusetts covered by the Phase II stormwater program requirements.

Monitoring Plan for TMDL Developed Under the Phased Approach

MassDEP recommends that the Towns of Brewster, Chatham, Harwich, and Orleans develop a detailed monitoring plan as part of the Comprehensive Wastewater Management Planning process and as part of the detailed plan for TMDL implementation process. The monitoring plan must be designed to determine if water quality improvements occur as a result of implementing this TMDL. This monitoring plan should be developed

and conducted in phases according to the identification of N reduction options as part of the adaptive management approach to achieving water quality standards. The Department recognizes the long-term nature of the time horizon for full implementation of the TMDL; however, reasonable milestones in the shorter term are necessary.
Growth should be guided by a consideration of water quality-associated impacts.

Reasonable Assurances

MassDEP possesses the statutory and regulatory authority, under the water quality standards and/or the State Clean Waters Act (CWA), to implement and enforce the provisions of the TMDL, including requirements for N loading reductions from on-site subsurface wastewater disposal systems. However, because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. Brewster, Chatham, Harwich, and Orleans have demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The Towns expect to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems, stormwater, and runoff (including fertilizers), and to prevent any future degradation of these valuable resources. Moreover, reasonable assurances that the TMDL will be implemented include enforcement of regulations, availability of financial incentives and local, state and federal programs for pollution control. Stormwater NPDES permit coverage will address discharges from municipally owned storm water drainage systems. Enforcement of regulations controlling non-point discharges include local implementation of the Commonwealth’s Wetlands Protection Act and Rivers Protection Act; Title 5 regulations for on-site subsurface wastewater disposal systems, and other local regulations such as the Town of Rehoboth’s stable regulations. Financial incentives include federal funds available under Sections 319, 604 and 104(b) programs of the CWA, which are provided as part of the Performance Partnership Agreement between MA MassDEP and EPA. Other potential funds and assistance are available through Massachusetts’ Department of Agriculture’s Enhancement Program and the United States Department of Agriculture’s Natural Resources Conservation Services. Additional financial incentives include income tax credits for Title 5 upgrades and low interest loans for Title 5 on-site subsurface wastewater disposal system upgrades available through municipalities participating in this portion of the state revolving fund program.

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Appendix A

Table A – 1: Summarizes the nitrogen concentrations for Pleasant Bay Embayment System (from Chapter VI of the accompanying MEP Technical Report)

Table VI-1. Measured total (DIN+PON+DON) and bioactive nitrogen (DIN+PON) data and modeled bioactive nitrogen concentrations for the Pleasant Bay estuarine system used in the model calibration plots of Figures VI-2 and VI-3. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means. Data represented in this table were collected in the summers of 2000 through 2005.

Bioactive Nitrogen	monitoring station	Total Nitrogen			Bioactive Nitrogen			model min (mg/L)	model max (mg/L)	model average (mg/L)
		data mean (mg/L)	s.d. all data (mg/L)	N	data mean (mg/L)	s.d. all data (mg/L)	N			
Meetinghouse Pond	PBA-16	0.724	0.218	83	0.407	0.351	90	0.351	0.401	0.380
Meetinghouse Pond	WMO-10	0.979	0.290	28	0.279	0.098	30	0.210	0.322	0.261
The River - upper	WMO-09	0.862	0.235	29	0.252	0.072	29	0.203	0.286	0.239
The River – mid	WMO-08	0.846	0.248	23	0.222	0.060	23	0.187	0.235	0.211
Lonnies Pond (Kescayo Ganset Pond)	PBA-15	0.777	0.188	80	0.281	0.103	86	0.241	0.260	0.250
Areys Pond	PBA-14	0.731	0.109	83	0.304	0.092	91	0.282	0.314	0.297
Namequoit River - upper	WMO-6	0.829	0.206	21	0.300	0.101	23	0.203	0.272	0.239
Namequoit River - lower	WMO-7	0.728	0.168	20	0.241	0.087	22	0.185	0.245	0.216
The River - lower	PBA-13	0.561	0.102	72	0.175	0.060	78	0.166	0.220	0.195
Pochet – upper	WMO-05	0.838	0.266	27	0.283	0.106	28	0.211	0.309	0.269
Pochet - lower	WMO-04	0.777	0.210	24	0.241	0.076	24	0.175	0.257	0.209
Pochet – mouth	WMO-03	0.716	0.239	39	0.180	0.063	39	0.163	0.202	0.183
Little Pleasant Bay - head	PBA-12	0.773	0.280	83	0.183	0.093	84	0.145	0.203	0.178
Little Pleasant Bay - main basin	PBA-21	0.565	0.174	51	0.135	0.038	52	0.133	0.187	0.162
Paw Wah Pond	PBA-11	0.707	0.216	75	0.268	0.160	79	0.231	0.286	0.257
Little Quanset Pond	WMO-12	0.599	0.116	22	0.205	0.071	24	0.220	0.240	0.229
Quanset Pond	WMO-01	0.562	0.149	79	0.189	0.063	87	0.176	0.208	0.191
Round Cove	PBA-09	0.707	0.230	83	0.246	0.097	84	0.222	0.266	0.241
Muddy Creek - upper	PBA-05a	1.257	0.368	25	0.700	0.411	27	0.660	0.690	0.674
Muddy Creek - lower	PBA-05	0.574	0.097	40	0.243	0.094	46	0.260	0.308	0.286
Pleasant Bay - head	PBA-08	0.439	0.099	83	0.162	0.063	86	0.132	0.162	0.149
Pleasant Bay - off Quanset Pond	WMO-02	0.555	0.144	34	0.174	0.049	38	0.153	0.166	0.160
Pleasant Bay- upper Strong Island	PBA-19	0.728	0.237	39	0.169	0.113	42	0.094	0.148	0.117
Pleasant Bay - mid west basin	PBA-07	0.434	0.118	79	0.161	0.054	84	0.163	0.174	0.168
Pleasant Bay - off Muddy Creek	PBA-06	0.489	0.117	67	0.188	0.057	70	0.187	0.199	0.192
Pleasant Bay - Strong Island channel	PBA-20	0.566	0.222	44	0.141	0.044	47	0.094	0.155	0.124
Ryders Cove - upper	PBA-03	0.718	0.255	97	0.254	0.114	100	0.234	0.260	0.250
Ryders Cove - lower	CM-13	0.417	0.071	86	0.159	0.044	92	0.117	0.196	0.158
Frost Fish - lower	CM-14	1.158	0.395	44	0.349	0.296	45	0.155	0.434	0.243
Crows Pond	PBA-04	0.838	0.325	96	0.208	0.093	97	0.158	0.165	0.162
Bassing Harbor	PBA-02	0.489	0.161	37	0.121	0.035	38	0.097	0.158	0.127
Pleasant Bay - lower	PBA-18	0.463	0.168	47	0.123	0.040	47	0.094	0.148	0.116
Chatham Harbor - upper	PBA-01	0.433	0.198	87	0.105	0.036	90	0.094	0.132	0.104
Chatham Harbor - lower	PBA-17	0.349	0.134	2	0.100	0.010	2	0.094	0.121	0.099
Chatham Harbor – lower (Flood Tide)	PBA-17a	0.232	0.044	17	0.094	0.020	18	-	-	-

Appendix B

Table B –1 Summarizes the present on-site subsurface wastewater disposal system loads, and the loading reductions that would be necessary to achieve the TMDL by reducing on-site subsurface wastewater disposal system loads, ignoring all other sources.

Table VIII-3. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Pleasant Bay system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present septic load (kg/day)	threshold septic load (kg/day)	threshold septic load % change
Meetinghouse Pond	5.140	0.000	-100.0%
The River – upper	2.071	1.036	-50.0%
The River – lower	2.871	1.436	-50.0%
Lonnies Pond	1.630	0.815	-50.0%
Areys Pond	0.778	0.389	-50.0%
Namequoit River	2.011	1.005	-50.0%
Paw Wah Pond	1.510	0.377	-75.0%
Pochet Neck	6.614	2.315	-65.0%
Little Pleasant Bay	4.512	2.256	-50.0%
Quanset Pond	1.403	0.701	-50.0%
Tar Kiln Stream	1.797	0.899	-50.0%
Round Cove	3.162	1.897	-40.0%
The Horseshoe	0.474	0.474	0.0%
Muddy Creek - upper	7.156	1.789	-75.0%
Muddy Creek - lower	6.340	0.000	-100.0%
Pleasant Bay	13.077	6.538	-50.0%
Pleasant Bay/Chatham Harbor Channel	-	-	-
Bassing Harbor - Ryder Cove	7.137	1.784	-75.0%
Bassing Harbor - Frost Fish Creek	2.200	0.000	-100.0%
Bassing Harbor - Crows Pond	3.326	3.326	0.0%
Bassing Harbor	1.400	1.400	0.0%
Chatham Harbor	14.195	14.195	0.0%
TOTAL - Pleasant Bay System	88.803	42.632	-52.0%

Appendix C

The Pleasant Bay Embayment System estimated wasteload allocation (WLA) from runoff of all impervious areas within 200 feet of waterbodies.

Watershed Name	Impervious subwatershed buffer areas[1]		Total subwatershed Impervious areas		Total Impervious subwatershed load	Total subwatershed load	Impervious watershed buffer area WLA	
	Acres	%	Acres	%	Kg/year	Kg/year	Kg/year[2]	%[3]
Pleasant Bay	43.1	12.2	321.1	7.6	894	43048	120.00	0.28
Chatham Harbor	5.4	10.5	1385.6	9.2	481	6241	1.87	0.03
Pochet Neck	14.8	5.7	76.5	9.0	260	4266	50.30	1.18
Meetinghouse Pond	5.4	11.8	42.7	12.9	193	2261	24.41	1.08
Lonnies Pond	1.5	12.7	16.2	8.2	87	890	8.06	0.91
Arey's Pond	1.6	3.7	12.4	5.2	58	476	7.48	1.57
Namequoit River	7.5	9.0	1385.6	9.2	97	999	.52	0.05
Upper River	3.7	7.7	20.5	9.5	87	1012	15.7	1.55
Lower River	4.8	10.2	34.9	9.0	144	2426	19.8	0.82
Paw Wah Pond	0.5	7.9	14.9	8.2	50	1055	1.68	0.16
Quanset Pond	0.5	2.0	1.5	7.6	71	712	23.43	3.29
Tar Kiln Stream	0.2	3.2	32.0	9.8	52	2258	0.33	0.01
Round Cove	39.2	12.3	218.4	8.0	154	1604	27.64	1.72
The Horseshoe	0.1	2.0	1.2	4.0	0.08	256	2.75	1.07
Upper Muddy Creek	4.4	4.0	128.4	12.5	395	3703	13.54	0.37
Lower Muddy Creek	3.2	6.2	78.2	10.3	381	3794	15.59	0.41
Ryder Cove	78.1	14.6	218.4	8.0	357	4057	127.66	3.15
Crows Pond	6.9	14.0	34.3	14.4	147	2045	29.57	1.45
Bassing Harbor	1.2	6.9	25.4	16.5	51	1000	2.41	0.24
Frost Fish Creek	4.6	7.2	31.0	13.4	104	1095	15.43	1.41
Total	226.7	10.7	4079.2	9.1	4063.08	83198	508.17	0.27

[1]The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated from GIS. Due to the soils and geology of Cape Cod it is unlikely that runoff would be channeled as a point source directly to a waterbody from areas more than 200 feet away. Some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of the wasteload allocation (WLA) it was assumed that all impervious surfaces within 200feet of the shoreline discharge directly to the waterbody.

[2]The impervious subwatershed buffer area (acres) divided by total subwatershed impervious area (acres) then multiplied by total impervious subwatershed load (kg/year).

[3]The impervious subwatershed buffer area WLA (kg/year) divided by the total subwatershed load (kg/year) then multiplied by 100.